UPPER INTERTIDAL ALGAL ZONATION ON BODEGA HEAD, SONOMA COUNTY, CALIFORNIA

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Several workers have studied intertidal zonation of marine algae along the Pacific coast of North America. Smith (1944) published the first records of vertical algal distribution from the Pacific coast. Doty (1946) correlated critical tide factors with zonation. From Washington, Rigg and Miller (1949) reported on intertidal plant and animal zonation; they compared both exposed and semi-exposed localities in the Neah Bay area.

In this paper I examine the intertidal zonation of the more conspicuous indicator algae at two localities (exposed and semi-exposed) on Bodega Head, a small peninsula surrounding Bodega Harbor, by estimating the percent cover in 10 by 10 cm quadrats. These algae include *Gigartina agardhii, G. papillata, Iridaea* spp., *Rhodomela larix, Endocladia muricata, Bossiella plumosa, Corallina vancouverensis,* and *Pelvetiopsis limitata.*

In addition, the vertical distribution of *Petrocelis fransiscana* was studied. West (1972) stated that *Petrocelis fransiscana* may be the tetrasporophyte of *Gigartina agardhii.* I shall examine if a correlation exists in the vertical zonations of *Gigartina agardhii, G. papillata,* and *Petrocelis fransiscana.*

Materials and Methods

The study was from 1 Apr to 1 Jun 1974. Four different stations were established. Stations A, B, and D were located on the exposed, western side of Bodega Head, approximately 100 m apart. Station C (unexposed) was located on the eastern side, near the harbor entrance. The slope on all stations was approximately 30–45°, and stations A, B, and D were oriented at the same angle to incoming waves. Heights above the MLLW (0.0 m level) were measured by means of a stadia rod, chalk line, and line level. Three 0.5 by 0.5 m quadrats were randomly placed (table of random numbers) along a horizontal transect at each level; each quadrat was divided into twenty-five 10 by 10 cm subquadrats. Percent cover in each of these subquadrats was estimated for the indicator algae and *Petrocelis fransiscana. Gigartina argardhii* and *G. papillata* were grouped together. Other workers have indicated how variable these two species are in terms of growth morphology (Abbott, 1972; Jensen and Tanner, 1973). Also, Abbott (1970) has stated that *Gigartina agardhii* might be considered a form of *Gigartina papillata.* I could not always distinguish between the two plants.

Most of the Corallines and *Iridaea* spp. were small plants, especially

on the exposed side of Bodega Head. The two Corallines were grouped together since they were growing intermixed with each other. The identification of very small *Iridaea* species was exceedingly difficult, but later observations showed these plants were mainly *Iridaea flaccida.*

The mean percent cover for the seventy-five 10 by 10 cm subquadrats at each tidal level was computed. Species that had an average of less than 10 percent cover on the exposed transects were omitted from the list. If the quadrats fell on tidepools, rock crevices, or surf channels, or if the degree of exposure was different from the general pattern, the quadrats were placed as close to the original place as possible (same tidal height).

Results

The mean percent cover for the 75 subquadrats at each tidal height is presented graphically in Figures 1 and 2. Three distinct algal zones are readily recognized both in the exposed and semi-exposed stations. The *Pelvetiopsis* zone has its peak distribution between 3.2 and 4.2 m (exposed) and between 1.8 and 2.7 m (semi-exposed). The *Endocladia-Gigartina-Petrocelis* zone has its peak distribution between 2.0 and 3.6 m (exposed) and between 0.6 and 2.0 m (semi-exposed). Finally, there is a Coralline-*Iridaea* zone from 2.4 m and below (exposed), and a *Rhodomela-Iridaea* zone from 1 m and below (semi-exposed).

The mussel zone at the exposed stations (1.2–3.2 m) was replaced by a barnacle zone at the semi-exposed station (1.5–2.1 m).

Discussion

Gigartina agardhii and *G. papillata* have a bimodal distribution (figs. 1 and 2, exposed and semi-exposed). Both peaks in this distribution were composed of roughly equal amounts of the two species. Thus, the bimodal distribution is not an artifact of the "grouping" type of sampling procedure.

In exposed sites *Gigartina agardhii, G. papillata,* and *Endocladia muricata* have a similar vertical distribution (fig. 1), and most likely compete for surface area. *Endocladia muricata* reaches a maximum percent cover only 0.15 m away from the low between the two peaks representing the maximum percent cover of *Gigartina agardhii* and *G. papillata.* Both of the peaks for maximum *Gigartina agardhii* and *G. papillata* percent cover lie within areas where *Endocladia muricata* is a substantial, if not dominant, component of the zone. The bimodal *Gigartina agardhii* and *G. papillata* distribution may be due to *Endocladia muricata*'s superior adaptability, and thus competiveness, at the 2.6 m level. But between 3.5–3.8 m *Gigartina agardhii* and *G. papillata* have a larger percent cover than *Endocladia muricata.*

In the semi-exposed area, there is a comparable situation, except that the heights of the two peaks in the *Gigartina agardhii* and *G. papillata* distribution are reversed. The drop between the peaks corresponds exactly to the barnacle zone (see results).

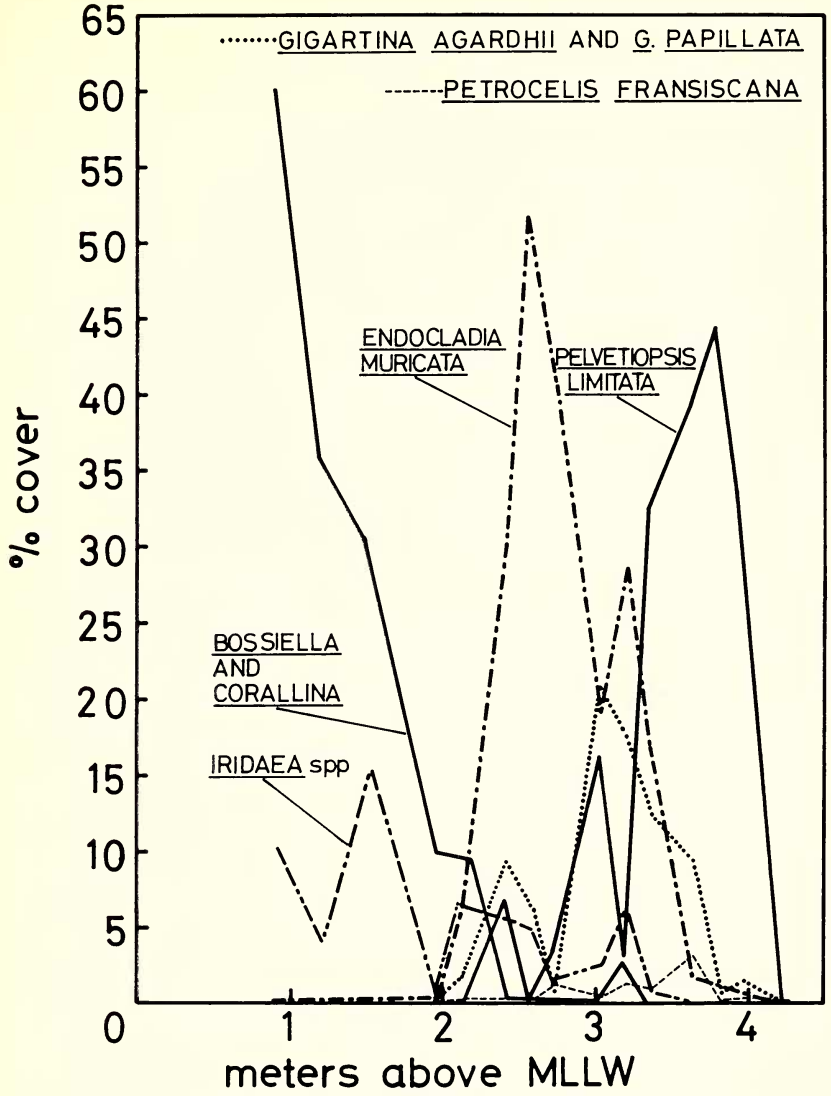

FIG. 1. Vertical distribution of algae at the exposed stations. Three zones can be recognized: the Coralline-*Iridaea* zone, the *Endocladia - Gigartina - Petrocelis* zone, and the *Pelvetiopsis* zone.

The separation of the peaks for *Pelvetiopsis limitata* and *Endocladia muricata* (exposed and semi-exposed) may indicate that ecological factors other than spatial ones determine their maximum percent cover. The overlap area may indicate that competition for space occurs at their interface.

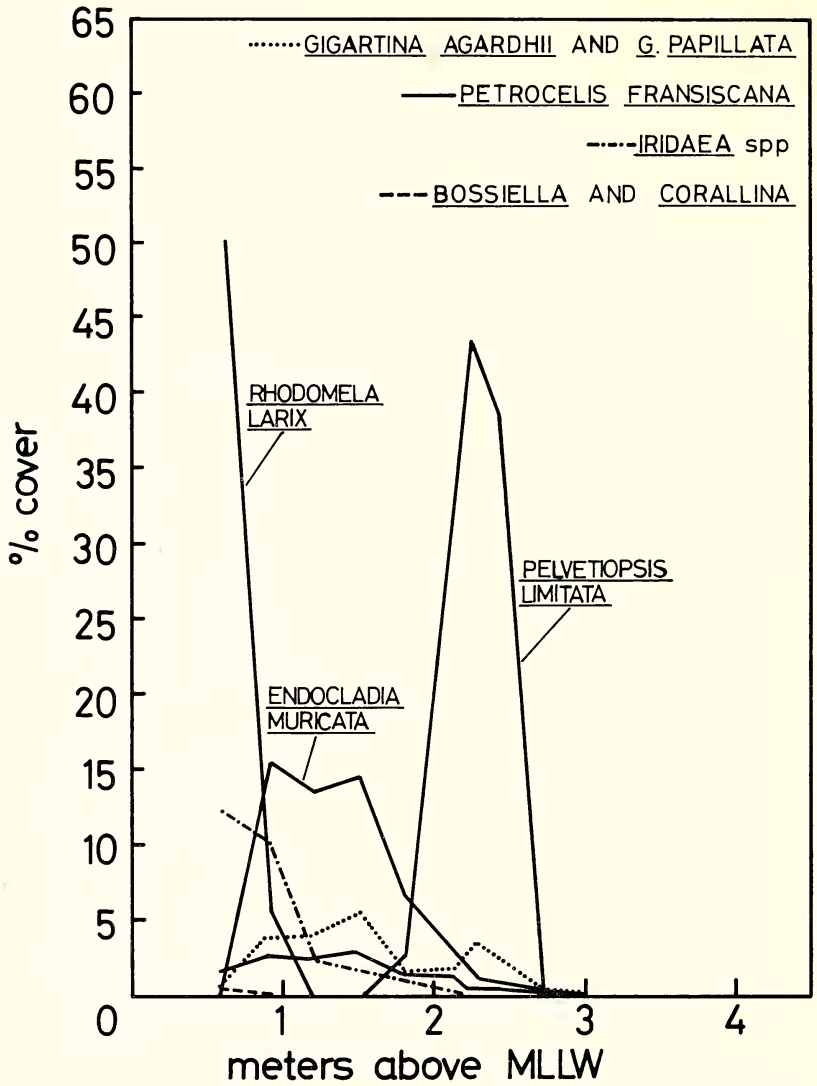

Fig. 2. Vertical distribution of algae at the semi-exposed station. Three zones can be recognized: the *Rhodomela - Iridaea* zone, the *Endocladia - Gigartina - Petrocelis* zone, and the *Pelvetiopsis* zone.

In comparing both the exposed and semi-exposed localities *Gigartina agardhii* and *G. papillata* do not form a distinct zone, but both species seem to be closely associated with *Endocladia muricata*. Other workers confirm this (Glynn, 1965; Rigg and Miller, 1949). The three plants are all resistant to desiccation and there seems to be competition for

space between *Gigartina agardhii, G. papillata,* and *Endocladia muricata.* In both exposed and semi-exposed situations, *Endocladia muricata* has a greater percent cover low in the intertidal, while *Gigartina agardhii* and *G. papillata* have a greater percent cover high in the intertidal. This agrees well with the literature, as Hinchmann (1964) found that the *G. papillata* complex was extremely resistant to desiccation.

From Figures 1 and 2, it appears that *Petrocelis fransiscana, Gigartina agardhii,* and *G. papillata* have similar distributions. This may support West's (1972) statement that *Petrocelis fransiscana* is the tetrasporophyte of *Gigartina agardhii,* although *G. agardhii* and *G. papillata* were recorded 0.30 m higher than *Petrocelis fransiscana* at the semi-exposed station, while *Petrocelis fransiscana* was found 1 m lower than *G. agardhii* and *G. papillata* at the exposed stations. *Gigartina agardhii* and *G. papillata* seem to withstand desiccation much more than *Petrocelis fransiscana.* On the exposed side of Bodega Head, *Petrocelis fransiscana* is scarce in the mussel beds, although I observed *Petrocelis* spots growing on the mussels. In general, *Petrocelis* spots found at both study localities were small, 1 to 3 cm in diameter. It appears that *Petrocelis fransiscana* is crowded out by mussels, barnacles, and other erect algae in these areas.

Glynn (1965) has pointed out how difficult it is to compare zonation studies done by different authors, even in the same locality. The vertical ranges of intertidal algae depend on several physical conditions, such as slope, degree of exposure to wave action, and surges in rock fissures.

Figure 3 compares the *Endocladia muricata* distribution from the semi-exposed station on Bodega Head with two other studies from the Pacific coast. Both Glynn (1965) and Rigg and Miller (1949) have their *Endocladia* zone almost entirely within the upper and lower limits as found on Bodega Head. Glynn (1965) found that the center of the *Endocladia-Balanus* association was 1.35 m above the MLLW, protected outer coast (fig. 3, the dark bar in the Monterey rectangle). The results from the semi-exposed station on Bodega Head agree well with his findings (fig. 3).

At Neah Bay (Rigg and Miller, 1949), the semi-exposed association was found to occur substantially higher than on Bodega Head (2.4 m vs. 1.3 m). The peak distribution of *Endocladia muricata* for exposed conditions on Bodega Head correlates well with their findings (2.6 m vs. 2.4 m). This indicates that the semi-exposed locality in the Neah Bay area is more exposed compared with the semi-exposed station on Bodega Head. The greater tidal range (about 3 m) at Neah Bay compared with Bodega Head (2.4 m) may also explain the difference.

Acknowledgments

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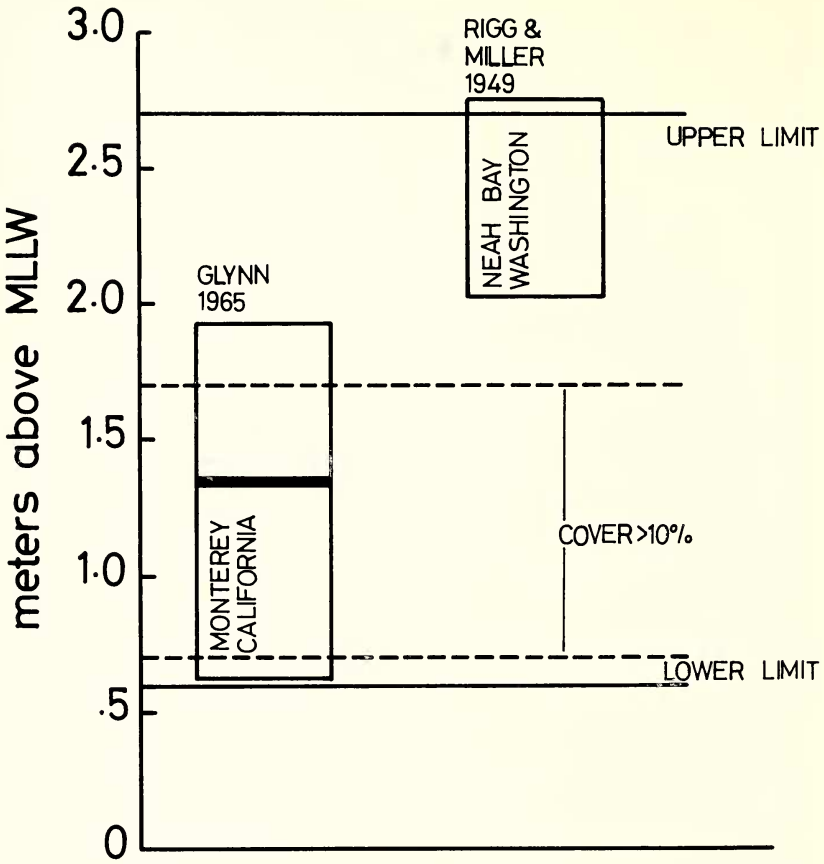

Fig. 3. Comparison of the vertical ranges of *Endocladia muricata* from the semi-exposed station on Bodega Head with the vertical ranges established by other workers for two places along the Pacific coast. The upper and lower limit lines and the two broken lines refer to Bodega Head. The dark bar in the Monterey rectangle refers to the center of the *Endocladia - Balanus* association.

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A NEW SPECIES OF PENSTEMON (SCROPHULARIACEAE) FROM MEXICO

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In collecting toward a flora of the Chihuahuan Desert region, James Henrickson and Thomas Wendt discovered the following new species, a close relative of *Penstemon barbatus* (Cav.) Roth, in the Sierra de la Madera west of Cuatro Cienegas in central Coahuila.

Penstemon henricksonii, species nova in sectione *Elmigera*; foliis basalibus ellipticis oblanceolatisve petiolatis, foliis caulinis ovatus ut in *P. cardinalibus*; floribus *P. barbato* simulantibus autem coloribus rubro-purpureis vel marroninis non coccineis; loculis antherae divaricatis marginibus minute acutidentatis. Figure 1.

Type: Mexico, Coahuila, ca 35 (air) km west of Cuatro Cienegas in Cañon de la Hacienda in limestone, Sierra de la Madera along trail southeast of road's end, in loamy oak-pine-fir forest, 7700 to 9000 ft, 5 Aug 1973, near 27°03′ N, 102°24′ W, *J. Henrickson and T. Wendt 11903*. Holotype: RSA; Isotypes: CSLA, TEX, MEXU, NY, ARIZ, US, UC, GH.

The species is also known from a collection of fruiting material: Sierra de la Madera, among similar associates, SW Rancho Cerro de la Madera, upper Cañon del Invierno, 2500 m, 27°05′ N, 102°28′30″ W, 27 Aug 1974, *Wendt and Lott 649b*, TEX.